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Soils Report

Two Eagle Vegetation Management Project

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SOILS REPORT

INTRODUCTION

The long-term sustainability of forest ecosystems depends on the productivity and hydrologic functioning of soils. Ground-disturbing management activities directly affect soil properties, which may adversely change the natural capability of soils and their potential responses to use and management. Forest soils are considered to be a non-renewable resource, as measured by human life spans, and maintenance or enhancement of soil productivity is an integral part of National Forest Management. The following section documents the soil resource effects of the proposed Two Eagle Project. Specific management indicators to be analyzed include soil productivity, and soil stability and erosion hazard potential. The report will analyze soil types within the activity area, their limitations, and offer methods that may allow for mitigation of limiting characteristics for a given soil or activity area.

Forest Service Manual 2520 Region 6 Supplement 2520-98-1 provides direction for the management of soils within activity areas in order to meet direction in the National Forest Management Act of 1976 and other legal mandates (Appendix A). To manage National Forest System lands under ecosystem management principles without permanent impairment of land productivity and to maintain or improve soil and water quality. The R6 soil quality standards are thresholds beyond which soil quality is adversely impacted. A minimum of 80% of an activity area must be left in an acceptable soil quality condition.

This analysis utilizes the best available soil survey mapping for the Wallowa-Whitman National Forests (NF). It is important to note that soil surveys are constantly evolving and changing, as is science. Landtype associations (LTAs) were also used in this analysis, and are based on vegetation zones, geology groups, and landforms (USDA Forest Service, 2006). The general use for LTA data is forest or area-wide planning and watershed analysis, appropriate for the scale of this project.

A suite of Best Management Practices (BMPs) and Project Design Criteria (PDC) will be integrated into the design of alternatives and the analysis of effects to ensure that relevant natural resources and social values are managed and protected in a manner consistent with policy, law, and regulation. BMPs and PDCs will also serve to ensure that implementation of the actions described in the Decision Notice are properly executed.

REGULATORY FRAMEWORK

The 1990 Wallowa-Whitman Forest Plan direction and the following Federal and State laws and regulations pertaining to the management of soil resources would be applied to the project:

- Organic Administration Act of 1897 (16 USC 473-475)
- Bankhead-Jones Act of 1937
- Multi-Use and Sustained Yield Act of 1960
- Oregon Forest Practices Act (1971)
- National Forest Management Act of 1976 (NFMA) 16 USC 1604(g)(3)(i)
- 36 CFR 219.20
- FSM 2500 Watershed and Air Management – Washington Office (WO) Amendments 2500-2010-1 and 2500-2010-2 and Pacific Northwest (R6) Supplement 2500-98-1 (Regional Soil Quality Standards)

Consistency with Forest Plan and Environmental Law

The Organic Administration Act of 1897 authorizes the Secretary of Agriculture to establish regulations to govern the occupancy and use of National Forests and "…to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States."

The Bankhead-Jones Act of 1937 authorizes and directs a program of land conservation and land utilization, in order to correct maladjustments in land use, and thus assist in controlling soil erosion, preserving natural resources, mitigating floods, conserving surface and subsurface moisture, protecting the watersheds of navigable streams, and protecting the public lands, health, safety, and welfare.

The Two Eagle project was designed to meet the standards set forth in the Oregon Forest Practices Act, FSM 2500- Watershed and Air Management, and Pacific Northwest Region (R6) supplement 2500-98-1 (Regional Soil Quality Standards).

The project complies with 36 CFR 219.20, which requires conservation and protection of soil and water resources and NFMA 16 USC 1604(g)(3)(E)(i), which requires that project activities do not produce substantial and permanent impairment of the productivity of the land. Additionally, NFMA requires that timber will be harvested from National Forest System lands only where soil, slope or other watershed conditions will not be irreversibly damaged.

The project, with described mitigation and BMPs in place, should be able to meet the intent and direction of the Multi-Use Sustained Yield Act of 1960. Sustained yield means achieving and maintaining into perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

The Region 6 Soil Quality Standards found in FSM 2500 Supplement 2500-98-1 (USDA, 1998), provide soil quality standards to assure the statutory requirements of NFMA Section 6(g)(3)(C) are satisfied. These soil quality standards protect the "productivity of the land" by setting limits for the degree of detrimental soil disturbance. The R6 supplement specifies that at least 80% of an activity area (defined as land area affected by a management activity, including landings and system roads) have soil that is in an acceptable soil quality condition. In other words, detrimental impacts (including past management impacts) shall be less than 20% of an activity area. In areas where less than 20% detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20%. In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.

While all these laws provide the foundation for ensuring that permanent productivity of the land is maintained, the forest plan also gives specific guidance on maintenance or protection of the soil resource at the forest level. Management plan standards for the Wallowa-Whitman National Forest will be met by this project, as seen below in Table 1.

METHODOLOGY

Data Sources, Assumptions and Limitations

Evaluation of Detrimental Soil Conditions (DSC)

The Wallowa-Whitman soil survey (OR631) data was used to determine the types of soils present within the planning area. The soil survey classification allows soils to be grouped to permit the largest number and the most precise predictions possible about responses to use and management (USDA Natural Resources Conservation Service, 1999). This system allows for monitoring results from one taxonomic unit to be related to other, similar taxonomic units. The Forest Service Activity Tracking System (FACTS) data was used for past timber harvest information. Reports from monitoring of past management activities on the Wallowa-Whitman were used in conjunction with project area field surveys to evaluate existing conditions (Howes et al., 1983). Detrimental soil conditions were assessed in the field in the summer of 2017 using the Forest Soil Disturbance Monitoring Protocol (FSDMP) (Page-Dumroese et al., 2009a; Page-Dumroese et al., 2009b). Surveys covered a representative sample of project units, proposed primarily for ground-based treatments, based on soil characteristics and past management activities. The FSDMP protocol provides a method for systematically quantifying soil conditions based on visual indicators. The Forest Soil Scientist determined which visual classes represent detrimental soil disturbance based on the characteristics of the soils within the project area. Visual disturbance class 3 was determined to be detrimental if they exceeded Region 6 Soil Quality Standards. Some instances of class 2 were judged detrimental due to compounding factors. System roads and landings were included in the field surveys and are included in estimates, per Region 6 Soil Quality Standards.

The existing and estimated values for DSC are not absolute and are best used to describe the existing soil condition. The calculation of the percentage of additional DSC from a given activity is an estimate, since detrimental disturbance is a combination of such factors as existing ground cover, soil texture, timing of operations, equipment used, skill of the equipment operator, the amount of wood to be removed, and sale administration. The DSC estimates of proposed activities also assume that BMPs would be implemented and that soil recovery occurs over time.

Predicted detrimental soil disturbance from proposed temporary roads are calculated based on average clearing width. Temporary road prisms are part of the productive land base as defined by NFMA Sections 4 through 7, and therefore, predictions of potential impacts on soil productivity are required. All temporary roads are estimated to average 12-14 feet in width of total disturbance resulting in 1.6 acres of detrimental disturbance per mile. All associated impacts from temporary road construction and closure are assigned to the related harvest units.

Soil Stability and Erosion Potential Hazard

The Landtype Associations (LTA) of Blue Mountains Ecoregion was used to determine the potential for surface erosion and soil stability. The LTA's of Blue Mountains Ecoregion is an ecological inventory that identifies similar physical and biological processes across the landscape. Features forming the basis for LTAs are landform expression, geology representing similar regolith and bedrock features, and potential natural vegetation used to identify climatic environments.

LTAs were used to analyze surface erosion by determining the potential for soil erosion upon removal of all vegetation material including the forest floor layer. These conditions often exist after severe fire that consumes 100% of the forest floor, on an unvegetated road cut/fill slope or on a skid trail. In these conditions, slope grades over 15% are generally steep enough to cause serious rill erosion and/or dry ravel. Surface erosion potential ratings were heavily weighted by slope gradient with a slight modification for the resistance or lack of erosion resistance from different soil textures.

Mass wasting was analyzed using LTAs, to look at the potential for deep seated mass movement and/or shallow rapid landslides. Site factors for deep seated landslide hazards include: easily weathered bedrock high in minerals weathering to clay, geologic structural features such as folding, faulting, and/or interbedded strata, geomorphic shape features (escarpments and converging concave topography), fine textured surficial deposits, slope gradients greater than 20 percent, indications of concentrated ground water, and indications of surface and subsurface water. Site factors for shallow-rapid landslides include: slope gradients greater than 40 percent, convergent drainages and/or catchment basins, unconsolidated coarse textured soils, interface of materials with discontinuous hydrologic properties, sparse vegetation patterns, geomorphic features (debris chutes associated with debris cones or alluvial fans), and high low order drainage density especially with parallel patterns.

Scientific Uncertainty and Controversy

Site and soil productivity relies on complex chemical, physical, and climatic factors that interact within a biological framework. For any given site and soil, a change in a key soil variable (e.g., bulk density, soil loss, and nutrient availability) can lead to changes in potential soil productivity. Defining the threshold at which productivity is detrimentally disturbed is controversial. The rationale for the 15% limit of change in soil bulk density was largely based on the collective judgment of soil researchers, academics, and field practitioners, and the accepted inability to detect changes in productivity less than 15% using current monitoring methods (Powers et al., 1990). Note that volcanic ash and pumice soils have a 20% limit of change in soil bulk density due to inherently low soil bulk density. Powers et al. (1990) states that the soil quality guidelines are set to detect a decline in potential productivity of at least 15%. This statement does not mean that the Forest Service tolerates productivity declines at this level, but that it recognizes problems with detection limits.

Soil quality standards are being studied by a cooperative research project called the North American Long-Term Soil Productivity Study (LTSP). The 5- and 10-year results were recently published (Page-Dumroese et al., 2006; Fleming et al., 2006; Sanchez et al., 2006a and 2006b). The LTSP study is ongoing and provides the best available science to resource professionals. In a 10-year study, no observed reduction in tree growth occurred as a result of compaction or organic matter removal in plots with soils generally similar to those found in the project area (silt loam) (Powers et al., 2005). These results are relatively short-term and involve many site- and soil-specific factors. Future results from the ongoing study should be helpful for assessing harvest practices on soil productivity.

Additional controversy surrounds the use of the term “irreversible” in the NFMA. The NFMA has guidelines that “insure that timber will be harvested from NFS lands only where soil, slope, or other watershed conditions will not be irreversibly damaged.” The DSC described in this analysis does not necessarily result in substantial and permanent impairment. Detrimental soil conditions are reversible if the processes (organic matter accumulation, moisture, topsoil retention, and soil biota) are in place and if time is allowed for recovery. Irreversible damage to soils in the project area could result from the loss of the volcanic ash cap through erosion or removal by excavation for temporary roads and/or skid trails. Soil recovery could still occur in remaining subsurface soils, yet the exceptionally high porosity and water-holding properties of the Mazama ash cap would likely be irrecoverable.

Resource Indicators and Measures

Table 1. Resource indicators and measures for assessing soil effects

Resource Indicator		Measure	Used to address: P/N, or key issue?	Source (LRMP S/G; law or policy, BMPs, etc.)?
Soil Productivity	>80% acceptable productivity potential	Acres of detrimental soil conditions	No	LRMP, FSM, Multi-Use Sustainable Yield Act
Soil Erosions	Soil erosion hazard	Acres of proposed ground-based activities on landtypes with high surface erosion hazard	No	
Soil Stability	Soil mass failure hazard	Miles of temporary roads on landtypes with high mass failure hazard	No	

Soil Productivity

1. Total acres of detrimental soil conditions

Soil productivity is a key factor to maintaining ecosystem function (Powers et al., 1998). Soil productivity is defined as the ability of the soil to supply the water and nutrients needed to sustain plant growth. Variables that influence soil productivity include physical soil characteristics, organic matter and soil biological activity. Past management activities in the analysis areas likely have caused Detrimental Soil Conditions (DSC) and impacted soil productivity. According to Region 6 Soil Quality Standards, detrimental soil conditions (e.g., compaction, displacement, puddling, severe burning, and erosion) from management activities should not exceed 20% of an Activity Area, including landings and system roads. Soil quality guidelines also include retention of soil organic matter, coarse woody material, and maintenance and protection of soil moisture regimes.

Physical Soil Characteristics

Physical soil characteristics include soil depth, porosity and bulk density. Changes in these occur most often when ground-based equipment makes repeated passes over the soil (Lull, 1959). These activities compact soils and if soils are moist enough, cause rutting and puddling. All of these changes to the physical soil characteristics reduce the pore space volume and water holding capacity. These physical changes reduce infiltration rates, slow soil drainage, impede root growth and reduce plant-available water and nutrients. Physical soil disturbances also decrease gas exchange, affecting both plants and soil biota. These physical changes to soil characteristics are classified as detrimental soil conditions (DSC).

Organic Matter

Organic matter in its various forms is critical for long-term site productivity and ecosystem sustainability. Regional direction states it should be maintained in amounts sufficient to prevent short or long-term nutrient and carbon cycle deficits and to avoid detrimental physical and biological soil conditions. Organic matter is particularly important for water retention, cation exchange, nutrient cycling, and erosion control (Page-Dumroese et al., 1991). Humus is decomposed organic matter. Duff and litter are partially decomposed leaves, needles and twigs less than three inches in diameter on the soil surface. In most coniferous trees, 85 to 90 percent of the total nutrients are contained in branches, twigs and foliage (Garrison et al., 1998). Coarse woody debris consists of woody stems greater than three inches in diameter and is essential to maintaining soil productivity (Harvey et al., 1994; Graham et al., 1994). This material has no effect on soil nitrogen or other nutrients regardless of decay stage and it can compete with vegetation for limited nutrients through immobilization (Busse, 1994; Prescott et al., 2002). Studies of post-harvest and site preparation activities showed that loss of organic matter can reduce soil productivity by changing soil physical, chemical and biological properties (Perry et al., 1989; Powers et al., 1990; Dyck et al., 1994; Everett et al., 1994; Harvey et al., 1994; Henderson, 1995; Jurgensen et al., 1997).

Soil Biological Activity

Soil organisms, including fungi and bacteria, drive the nutrient cycling process by decomposing organic matter and mineralizing nutrients for use by plants. Soil organisms depend on organic matter for the nutrients they need to carry out their life processes. Decomposed large woody debris provides habitat for the survival of mycorrhizae fungi. These fungi form a symbiotic relationship with tree roots, increasing water and nutrient uptake by the trees and the fungi (Perry et al., 1990).

Soil Erosion

1. Acres of proposed harvest on landtypes with high surface erosion hazard

An erosion hazard assessment was used to summarize surface erosion hazards in the project area from harvest activities. Harvest activities can decrease effective ground cover and increase surface soil compaction. On soils with high surface erosion hazard there is a much higher potential for sheet, rill, and gully erosion, and/or water quality degradation from sediment or nutrient enrichment into waterways.

Surface erosion is defined as the detachment and transport of soil particles by running water, waves, currents, moving ice, wind, or gravity (Armantrout, 1998). The main types of surface erosion are sheet, rill, and gully erosion (Brady and Weil, 1999). In sheet erosion, soil is removed more or less uniformly from the ground surface by raindrop splash. As this overland flow is concentrated, small channels develop (rills), and rill erosion occurs. Gully erosion results when the volume of water is further concentrated. The force of water cuts deeper into the soil, enlarging rills into larger channels termed gullies. Surface erosion is most serious on bare, non-vegetated soils surfaces where sheet and rill erosion are responsible for most soil loss. Erosion is infrequent on undisturbed forest soils for two reasons:

a. Abundant organic matter provides a protective layer on the soil surface that reduces the impacts of raindrops and allows water to infiltrate; and

b. The surface soil below the organic layer is by nature porous, allowing water to infiltrate into and through the soil profile (Goldman et al., 1986).

Soil erosion can occur when the surface soil is compacted or when the loose surface soil and its protective layer of organic material are changed by management activities. Compaction, rutting and puddling reduce the movement of water into the soil and tend to channel and concentrate water. As a result, run off (overland flow) is increased and carries soil particles with it. If the forest floor is disturbed, then runoff and erosion rates can increase by several magnitudes. Disturbance can be natural, such as wild fire, or human-induced, such as harvesting or prescription-burning for ecosystem management. When organic matter is removed, soil pores can be plugged by impact from raindrops resulting in overland flow and increased rates of soil erosion. Soil erosion can result in loss of soil productivity due to surface soils moving downslope and thus removing the materials with the greatest ability to hold moisture and nutrients. According to Region 6 Soil Quality Standards, for planning or implementation monitoring to meet acceptable levels of soil loss and soil management objectives, the minimum percent effective ground cover following cessation of any soil-disturbing activities is found in Table 2.

Table 2. Region 6 Soil Quality Standard for Minimum Percent Effect Ground Cover

	Minimum Percent Effective Ground Cover	
Erosion Hazard Class	**1st Year**	**2nd Year**
Low (Very slight-slight)	20-30	30-40
Medium (Moderate)	30-45	40-60
High (Severe)	45-60	60-75
Very High (Very Severe)	60-90	75-90

Effective ground cover is defined as the basal area of perennial vegetation, plus litter and coarse fragments (greater than 2mm sizes), including tree crowns and shrubs that are in direct contact with the ground. Exceptions may occur where specific projects meet erosion control objectives without meeting the ground cover objectives stated above.

Soil Stability

1. Miles of proposed temporary roads used on landtypes with a high subsurface erosion hazard

Mass wasting is the downslope movement of large mass of unstable soil, rock, and other debris due primarily to the forces of gravity (Brady and Weil, 1999; Brooks et al., 1997). Mass wasting can be caused by man-made disturbances or natural events, such as wildfire followed by high-intensity precipitation. Some areas are prone to mass failures because of the nature of the bedrock geology or soil. There are a wide variety of types of mass wasting events, but the ones of most concern are debris avalanches (including debris torrents and flows) and landslides. Other types of mass wasting events occur, but these two general categories account for the greatest impacts. Debris avalanches involve the rapid movement of soil, rock, and organic debris in stream channels or dissections because of saturated soils, high streamflows, or other upslope mass movements. If the material is primarily saturated soil, it may liquefy and move as a mudflow. Landslides occur with a sudden shear failure and downhill movement of soil and/or rock materials, usually under very wet conditions, as a result of oversteepening and the reduction of internal friction.

Management activities can saturate a soil by channeling water and concentrating it onto a limited area, for example, below a road culvert or a rutted skid trail. All mass failures triggered by human causes are classified as DSC. These disturbances cause long-term changes in soil productivity that can last centuries.

Spatial and Temporal Bounding of Analysis Area

The analysis area forms the boundary for the direct, indirect, and the cumulative effects in this soils analysis. It consists of the proposed treatment units and temporary roads for the Two Eagle Project. This analysis area was selected because it is where the effects of implementing the proposed activities would occur. The effects on soils would not extend beyond the analysis areas proposed for treatment. Natural and human-induced erosional processes may transport detached soil to a new location, if this occurs it is unknown if some portion of this material will end up outside of the project boundary.

The temporal boundaries for analyzing effects start from the initiation of historic forest activities, because soil disturbance can remain on the landscape for many decades. Short-term impacts are considered to be within 5 years and long-term effects being those that last for more than 5 years. Effects that are eliminated over the natural course of a single growing season are not considered effects because they are so short lived.

AFFECTED ENVIRONMENT

Table 3. Resource indicators and measures for the existing condition

Resource Indicator		Measure	Existing Condition
Soil Productivity	>80% acceptable productivity potential	Acres of detrimental soil conditions	158
Soil Erosion	Soil erosion hazard	Acres with high surface erosion hazard	0
Soil Stability	Soil mass failure hazard	Acres of high mass failure hazard	345

Soil Productivity

In order to determine the existing condition of soils within the proposed activity areas, field investigations were conducted to determine if and how existing soil condition was affected by past management activities or other dispersed activities (e.g., off-highway vehicle travel and firewood cutting). In addition, areas with proposed activity areas that would require Design Criteria to address conditions, such as sensitive soils that are wet, steep, or had evidence of past harvest that caused compaction, displacement, rutting, puddling, or soil erosion, were identified.

Most soils on the Wallowa-Whitman National Forest, including those within the project area, have a surface that formed in or is strongly influenced by volcanic ash loess and, thus, are similarly classified. Since most soil quality monitoring on the Wallowa-Whitman National Forest has occurred on soils that have a volcanic ash-influenced surface, there are a large number of both quantitative and qualitative ratings that relate to soils types found in the project area. This information has two valuable implications;

a. We can estimate the amount of detrimental soil disturbance that exists from past management activities by doing transects and observing the amount of visible detrimental disturbance present and

b. We can estimate the amount of detrimental soil disturbance to expect from proposed management activities on given soil types and thus estimate the effects on the soil resource.

Table 4 lists LTA map units for the activity areas. Productivity of the landtypes in the Two Eagle Project area is dominantly moderate to high. All soils within the proposed activity area, with the exception of shallow, rocky inclusions, support forest vegetation.

Table 4. Landtype Association soil productivity interpretations in Two Eagle project area

Landtype	Relative Productivity	Ash Influence	Sensitive	Acres
116	High	Thick Volcanic Ash	Yes	956
117	High	Thick Volcanic Ash	Yes	1643
131	High	Thick Volcanic Ash	Yes	2410
132	Low to Moderate	Thick Volcanic Ash	Yes	967
166	Moderate	Thin and Thick Volcanic Ash	No	370
167	Moderate	Thick and Mixed Volcanic Ash	No	457
168	Moderate	Thick and Mixed Volcanic Ash	No	129
216	Very Low to Moderate	Mixed Volcanic Ash	No	60
418	Moderate	Mixed Volcanic Ash	No	216

Sensitive Soils

Dry meadows and lithosols are considered sensitive soil types because of their shallow soil depth and inability to recover from disturbance events. There are dry meadows and lithosols scattered on plateau tops and ridges throughout the Two Eagle project area. These areas are defined as having thin, rocky soils with drought tolerant plants (Johnson and Simon, 1987). These soils have more rock and clay than soils influenced by loess or volcanic ash. When located on concave surfaces, these soils are often saturated until mid to late July. Disturbance tends to disrupt the rock-moss-plant mantle resulting in exposed bare ground, loosened surface rock, and a decline in principle grass species. Care must be taken to avoid these areas when choosing landing sites and skid trail locations.

Sensitive soils contain an excess of soil moisture either yearlong or on a seasonal basis and have an udic soil moisture regime. Disturbance on sensitive soils can lead to loss of soil productivity. Areas of sensitive soils typically require Design Criteria for protection.

Landtype 116 and 117 consists of Udivitrand soils which have a thick ash cap and Udic (moist) soil moisture. Ash has a low bulk density and bearing strength, which enables a high water holding capacity.

The low bulk density also increases the potential for rutting and compaction. Ground based equipment should be carefully managed and confined to periods when soil is dry, frozen, or snow covered.

Landtype 131 map units consist of glacially formed subsurface soils, with high potential for ponding and wet meadows. Due to the close proximity of streams, this Landtype has high sediment delivery efficiency. Tractor operation should be carefully managed and confined to periods when soil is dry, frozen, snow covered or operating on two feet of slash. Avoidance should be practiced to avoid saturated soils.

Landtype 132 map units consist of 30 percent rock outcrops and Vitricryand soils which have a thick ash cap. These soils have moderately coarse, glacially-formed subsurface soils which have an increased potential for erosion if the overlying volcanic ash is displaced. Volcanic ash has a low bulk density and bearing strength, which enables a high water holding capacity. The low bulk density also increases the potential for rutting and compaction. Ground based equipment should be carefully managed and confined to periods when soil is dry, frozen, or snow covered.

Soil map unit 9701RW consists of 40% histosol (Bycracky series) and 25% aquic mollisol (Habenome series). The bycracky series consists of very deep, very poorly drained soils on basin floors and benches of glaciated mountain slopes. Bycracky soils formed in peat mixed with or overlying volcanic ash overlying lacustrine sediments or glaciofluvial material derived from mixed materials dominated by granitic rocks. The Habenome series consists of very deep, poorly drained soils in basins and on benches of glaciated mountain slopes. Habenome soils formed in alluvial, lacustrine and glaciofluvial materials derived from mixed sources dominated by granitic rocks. These soils can be identified in the field by wet meadow vegetation. Avoidance should be practiced during any project activities that occur on the westerly side of units 52 and 90.

Detrimental Soil Conditions

Several vegetation management project have been completed in portions of the project area over past decades. Multiple entries over many decades for timber harvest and other purposes have occurred, and residual soil disturbance is wide spread in extent. Timber harvests in the Two Eagle project area that occurred before the 1990 Forest Plan, included improvement cutting, commercial thinning, overstory removal, seed tree, and single-tree selection cutting. Before the current forest plan, skid trails often were not pre-designated and as a result were randomly distributed throughout the old units. Skid trails were spaced approximately 50 to 100 feet apart. Past activities that occurred after the 1990 Forest Plan, included single-tree selection, salvage cutting, and one seed-tree cutting. These past activities showed a reduction in detrimental impacts to soils with observed levels of detrimental soil conditions (DSC's) within the 6-12% range based on past monitoring data (Bliss, 2006). Table 5 below, has existing conditions results of units in the Two Eagle Project area.

Table 5. Existing Condition results of proposed activity units including system roads.

Unit	Acres	Prescription	Existing Condition DSC (%)
1	31	Improvement Cut	5%
2	38	Improvement Cut	5%
3	31	Whip Felling	5%
4	15	Improvement Cut	8%
5	40	Improvement Cut	18%
7	10	Improvement Cut	5%
8	26	Improvement Cut	5%
9	12	Improvement Cut	5%
11	21	Improvement Cut	5%
12	12	Whip Felling	5%
13	18	Improvement Cut	6%

14	10	Improvement Cut	5%
15	12	Improvement Cut	5%
16	16	Improvement Cut	5%
17	5	Improvement Cut	5%
18	17	Improvement Cut	5%
21	66	Commercial Thin	16%
22	99	Improvement Cut	5%
23	29	Commercial Thin	6%
24	16	Commercial Thin	6%
25	8	Commercial Thin	9%
26	10	Commercial Thin	23%
27	33	Commercial Thin	23%
28	20	Commercial Thin	6%
29	13	Commercial Thin	6%
30	8	Improvement Cut	5%
31	9	Improvement Cut	5%
32	8	Commercial Thin	5%
33	18	Commercial Thin	5%
34	49	Improvement Cut	7%
35	2	Whip Felling	5%
36	9	Improvement Cut	5%
37	5	Whip Felling	5%
38	21	Improvement Cut	5%
40	23	Commercial Thin	5%
41	7	Commercial Thin	5%
42	10	Improvement Cut	5%
43	92	Improvement Cut	5%
45	50	Commercial Thin	5%
48	15	Commercial Thin	5%
49	8	Improvement Cut	5%
50	13	Shelterwood	5%
51	18	Improvement Cut	5%
52	27	Improvement Cut	5%
53	38	Pre-Commercial Thin	23%
54	11	Commercial Thin	5%
55	14	Improvement Cut	17%
56	5	Improvement Cut	23%
57	7	Whip Felling	5%
58	6	Improvement Cut	5%
59	10	Whip Felling	5%
60	14	Improvement Cut	23%
62	10	Improvement Cut	14%
63	16	Pre-Commercial Thin	23%
64	7	Improvement Cut	5%
66	54	Improvement Cut	5%
68	18	Improvement Cut	6%
69	9	Whip Felling	5%
71	22	Improvement Cut	5%
74	22	Improvement Cut	5%
75	13	Improvement Cut	6%
78	24	Patch Opening	5%
79	11	Patch Opening	6%

80	31	Improvement Cut	5%
84	1	Seed Tree	5%
85	25	Improvement Cut	5%
86	14	Commercial Thin	5%
88	23	Improvement Cut	19%
89	65	Improvement Cut	6%
90	25	Whip Felling	22%
92	32	Pre-Commercial Thin	23%
93	7	Pre-Commercial Thin	22%
94	19	Pre-Commercial Thin	23%
95	2	RHCA Patch Opening	6%
96	7	Commercial Thin	16%
97	17	Improvement Cut	5%
98	13	Improvement Cut	5%
102	10	Pre-Commercial Thin	5%
112	4	RHCA Patch Opening	9%
113	1	RHCA Patch Opening	10%
115	34	Pre-Commercial Thin	23%
116	52	Improvement Cut	21%
117	27	Improvement Cut	22%
118	22	Shelterwood	5%
119	8	Shelterwood	5%
120	14	Shelterwood	5%
121	13	Whip Felling	5%
123	18	Whip Felling	5%
124	27	Whip Felling	5%
126	11	Whip Felling	23%
127	6	Whip Felling	23%
128	13	Whip Felling	5%
129	7	Whip Felling	7%
130	40	Whip Felling	23%
131	8	Whip Felling	5%
132	18	Whip Felling	5%
133	3	Whip Felling	8%
135	18	Whip Felling	5%
138	31	Whip Felling	6%
139	11	Pre-Commercial Thin	23%
140	21	Pre-Commercial Thin	23%
145	69	Whip Felling	13%
147	31	Whip Felling	5%
148	107	Whip Felling	20%
149	6	Whip Felling	5%
150	23	Pre-Commercial Thin	17%
151	23	Pre-Commercial Thin	23%
152	55	Pre-Commercial Thin	23%
153	27	Pre-Commercial Thin	23%
156	30	Whip Felling	5%
157	21	Whip Felling	5%
158	10	Whip Felling	22%
159	15	Whip Felling	23%
160	35	Whip Felling	5%
161	22	Whip Felling	11%

162	7	Pre-Commercial Thin	23%
163	8	Pre-Commercial Thin	23%
164	19	Pre-Commercial Thin	23%
165	29	Pre-Commercial Thin	14%
166	5	Pre-Commercial Thin	7%

Soil Productivity Trends

Soil quality in the Two Eagle Project Area is stable to trending upward. Most disturbed soils have abundant organic matter and roots throughout the upper soil layers. Evidence of old compaction, evident in soils with platey structure, have begun to recover from established root systems of vegetation and rodent burrows. During field surveys, many legacy trails had an adequate amount of effective ground cover, while some trails and landings had exposed mineral soil due to soil bulk density being too high for root penetration. In most cases, skid trails and landings represent the greatest amount of legacy disturbance in the project area. Literature indicates that disturbed soils improve by means of plant growth, bioturbation, freeze/thaw cycles, wet/dry cycles, and organic matter additions, all of which naturally occur in the project area. These natural processes effectively improve compacted soils over time (Lull, 1959). Compaction recovery rates are highly variable with an expected range of 10 to 70 years (Gonsior, 1983). The target downed wood for dry ponderosa pine sites is 5 to 10 tons/acre and 10 to 15 tons/acre for mixed conifer sites for moderating soil productivity while minimizing fuels hazard (Soil PDC 13).

Soil Erosion

Soil erosion is a natural process that can be accelerated by land management activities; it depends on soil texture, rock content, vegetative cover and slope. Erosion hazards can be ameliorated by operating on slopes less than 30 percent with good vegetative cover. Vegetation binds soil particles together with roots and vegetative cover, and protects the soil surface from raindrop impact and dissipates the energy of overland flow. Table 6 lists the LTA map units for activity areas in Two Eagle. The dominant erosion risk for the landtypes in the Two Eagle Project Area is low to moderate. Landtypes within project activity units include Trough Floors (34%), Gentle Mountain Slopes (24%), Steep Mountain Slopes (21%), Trough Walls (15%), and Canyons (5%). The runoff potential for a majority (59%) of the project activity units is low. There is 23 percent of the project activity units that have moderate runoff potential, which means runoff is somewhat well regulated but concentrated flows routed into first order drainages from infrequently large storms or snowmelt have the potential for high peak runoff flows. There is 18 percent of the project activity units that have flashy runoff potential, and do not absorb a great deal of surface water, therefore runoff is poorly regulated and concentrated flows are routed rapidly into first order drainages. The high rock fragment content and coarse texture of most subsurface horizons also promote water movement through soils. Runoff from these soils should not be substantial with the erosion control plan and project design criteria.

Table 6. Landtype Association soil erosion interpretations

Landtype	Surface Erosion Hazard - Disturbed	Surface Erosion Hazard - Undisturbed	Acres
116	Low to Moderate	Low	956
117	High	Low	1643
131	Low to Moderate	Low	2410
132	Moderate to High	Low to High	967
166	Low to Moderate	Low	370
167	High	Low	457
168	High	Moderate	129
216	Low to Moderate	Low	60
418	High	Moderate	216

Soil Stability

The dominant mass failure hazard rating for the Two Eagle Project Area is low. The majority of landtypes in this project do not have increased potential for mass failure. Landtype 132 has moderate to high shallow-rapid landslide hazard rating (13 percent of project area). Landtype 168 has high shallow-rapid and moderate to high deep-seated landslide hazard ratings (2 percent of project area). Landtype 418 has a high shallow-rapid landslide hazard rating (3 percent of project area). Slopes over 40% are at higher risk for landslide. Some terrain is "hummocky," indicating past unstable slopes, but no recent mass failures such as slumps or debris flows were found, even though much of the area has been previously harvested.

Table 7. Landtype Association soil stability interpretations

Landtype	Mass Failure Hazard (Shallow Rapid)	Mass Failure Hazard (Deep Seated)	Acres
116	Low	Low	956
117	Moderate	Low to Moderate	1643
131	Low	Low to Moderate	2410
132	Moderate to High	Low to Moderate	967
166	Low	Low	370
167	Moderate	Low to Moderate	457
168	High	Moderate to High	129
216	Low	Low	60
418	High	Moderate	216

ENVIRONMENTAL CONSEQUENCES OF NO ACTION

The analysis of effects for soils assumes that all Design Criteria outlines in Chapter 2 would be effectively implemented. The analysis will show the expected amount of detrimental soil disturbance resulting from the implementation of the action alternatives and will describe the risk that the expected amount of disturbance would be exceeded.

Soil Productivity

The No Action alternative would not cause short-term effects on the Soil Resource over and above existing condition. No additional road building, timber harvest, prescribed burning, or fuels reduction would disrupt natural soil processes.

Physical Soil Characteristics

The No Action alternative would not cause soil compaction, rutting, puddling, or soil displacement. Undisturbed soils would remain so. Soil productivity in areas where past timber management compacted soils would slowly improve as plant roots, soil organisms, and freeze-thaw events loosen the soil. Most soil disturbances would recover after 70 years (Gonsior, 1983). Sites that are slightly compacted would recover in fewer than 70 years. Displaced, rutted, and puddled soils would have reduced productivity for a longer time than compacted soils.

Organic Matter

Standing dead trees would eventually fall over and contribute coarse-woody debris and additional organic material would be recruited through natural mortality. Fine-woody debris would remain on site. Soil organisms would decompose the organic materials adding humus to the soil. Nutrients associated with this material would slowly become available for plant growth. As the tree canopies close and shade the soil surface, decomposition rates would slow, allowing organic matter and nutrients to accumulate on the soil surface. This process would continue until another major disturbance, such as fire or a windstorm, opens the tree canopy and speeds up the recycling process again.

Soil Biological Activity

Microorganism populations would fluctuate with the changes in microclimate and supply of organic matter on the soil surface. These changes would be in response to the changing vegetation as a result of natural events such as fire, wind throw, and other sources of natural vegetation mortality. Any changes would be buffered by the capability of soil microbial communities to adapt to changing conditions on very short time scales (Schmidt et al., 2007).

Soil Erosion

The No Action alternative would allow any current soil erosion to decrease as vegetation returns to soils that lack plant cover. Wildfires could cause short-term increases in soil erosion. Soil erosion rates would fluctuate with natural changes in vegetation and associated ground cover.

Mass Failures

The No Action alternative would not change the risk of mass failures within the project area. Mass failure is expected to continue at low levels as a result of natural processes.

ENVIRONMENTAL CONSEQUENCES OF ALTERNATIVE 2, 2 MODIFIED, AND 3

Direct and Indirect Effects: Soil Productivity

Physical Soil Characteristics

Tractor Harvest

These operations would result in direct and indirect effects on soil physical characteristics within the boundaries of proposed activity areas. Most detrimental effects would be concentrated on the proposed skid trails, temporary roads, and landings within or associated with timber harvest units. Minimizing the area occupied by landings and skid trails to reduce the detrimental effects on soil productivity from changes in physical soil properties is recommended in several papers (Garland, 1983; Page-Dumroese, 1993; Williamson et al., 2000). Skid trails comprise the majority of the detrimental disturbance, which is largely compaction and displacement. The same applies to landings with the addition of more soil puddling and charring from burning landing piles. Local data (Bliss, 2006) indicate new ground-based yarding activities would create 5 to 10 percent DSC before implementation of any mitigations. These results are based on past monitoring which shows that about 50 percent of skid trail width has been observed to be detrimentally compacted and displaced. Acres of skid trails are assumed to be 1/10th of the unit and only half are considered to produce new DSCs. New skid trail DSCs are calculated by taking half of the estimated skid acres and dividing that value by the unit acres. For tractor harvest, that number will always be 5.0%. Landings occur approximately every 7 acres of an activity area and occupy a space of approximately ¼ acre. The range of possible effects is wide due to several variables including type of harvest equipment used, operator skill, layout, current infrastructure, past harvest effects, landform characteristics, and soil site conditions.

Where processor/forwarder harvest systems are proposed to be used, DSC are estimated to be 4 to 6 percent. Processor forwarder effects are less because they use wider tires with less ground pressure, and operate on slash, which helps reduce soil compaction and displacement. However, these effects are based on adequate quality and quantity of slash to operate on. If the site is unable to support adequate quality and quantity of slash to prevent compaction and displacement, the harvest system no longer provides a mitigated effect.

In addition to using designated skid trails and landings, there would be potential to reduce soil effects further by limiting equipment operation, to the extent possible, on skid trails when soils are drier than field capacity (McNabb et al., 2001; Startsev et al., 2001). Rutting and puddling are most often associated with logging on wet soils (Williamson et al., 2000). Most summer logging would occur when soils are drier than field capacity. By operating on low soil moisture conditions we have the potential to reduce the amount of detrimental disturbance from skidding operations.

Skyline Harvest

These operations would result in direct and indirect effects on soil physical characteristics within the boundaries of the proposed activity areas. Effects would be less than those from ground-based operations. Local monitoring data shows that skyline yarding creates 1 percent detrimental soil conditions per unit (Wallowa-Whitman NF, 2004). There is approximately 1 percent DSC created from l pile burning associated with skyline landings (Wallowa-Whitman NF, 2004).

Mechanical Non-Commercial Thinning

These treatments include precommercial thinning, mastication, and grapple piling. Grapple piling and pile burning generates approximately 3% DSC and is prescribed in commercial thinning and non-commercial thinning units (Wallowa-Whitman NF, 2004). Actual DSC would be affected by variables such as soil density, percent rock in/on the soil surface greater than 3 inches in diameter, soil moisture, ground cover (vegetation type and woody debris tonnage), type of equipment used, and operator skill. Physical forest floor impacts would be limited to track deformation and minor amounts of displacement (less than 100 square feet). Use of ground-based mastication equipment would have direct and indirect effects on soil physical characteristics within the boundaries of the proposed units. There would be potential to greatly reduce these effects by limiting equipment operation to dry soils. Soil compaction is reduced when soils are drier than field capacity (McNabb et al., 2001; Startsev et al., 2001). Rutting and puddling are most often associated with ground-based mechanical equipment operation on wet soils (Williamson et al., 2000). Mechanical mastication would occur only when soils are drier than field capacity. Mastication treatments would substantially increase woody debris (Harrod et al., 2009). This heavy slash is effective for buffering the effect of ground-based mechanical equipment operation on mineral soil (Han, 2006; Han et al., 2006). A significant relationship exists between the presence of bare ground and the potential for increased compaction (Hatchett et al., 2006). Further soil protection would be expected through retention of forest floor due to absence of displacement normally associated with ground-based skidding of logs.

Hand Non-Commercial Thinning

Hand thinning and/or piling would not generate detrimental soil conditions, but the associated pile-burning could result in minor changes to soil structure where temperatures between 220 and 460 C are generated (DeBano et al., 1998). No significant effects to soil bulk density, infiltration capacity or soil moisture content are expected (Seymour et al., 2004).

Riparian Treatments

Alternative 2 and 2 Modified proposes removing co-dominant trees and ladder fuels in small patches around cottonwoods and western larch on approximately 7 acres. Trees would be felled by hand only and trees would be lopped and scattered. Tree removal would be allowed by mechanical equipment that does not leave existing roads. No detrimental soil disturbance would result from the hand treatment or mechanical equipment.

Temporary Roads

There are 5.25 miles of temporary roads proposed in Alternative 2/Alternative 2 Modified, and 3.57 miles of temporary roads proposed in Alternative 3. Average clearing width is assumed to be 12 feet for temporary roads, therefore they would create 1.6 acres of DSC per mile (Table 8). All temporary roads used (existing and new) for this project would be decommissioned, also referred to as hydrologically obliterated, by any site-appropriate combination of the following:

- Masking or obliterating entrances,

- Removing any installed culverts or temporary bridges,
- Recontouring the entire template to natural ground contour,
- Where recontouring is unnecessary, scarify with excavator teeth to a depth equal sufficient to ameliorate the presence of detrimental soil compaction (usually between 2 and 12 inches),
- Seeding with the native plant mix as specified by the local Botanist,
- Placing woody material on the template, and
- Planting native shrubs/trees to augment natural vegetation.

Re-contouring activities would not ameliorate the long-term impacts to soil productivity immediately, but would improve soil conditions compared to those of an existing or abandoned road. The establishment of vegetation and associated additions of organic matter would encourage recovery over time. Re-contouring would provide a suitable seed bed for native forest vegetation while increasing soil hydraulic conductivity, organic matter, total carbon, and total nitrogen (Lloyd et al., 2013). These conditions would likely accelerate the recovery of the soil productivity.

Erosion is expected from temporary road construction where native surfaces are exposed to rainfall impact and overland flow. Some areas would likely have short-term increases of soil erosion, however erosion rates would decrease as roads are obliterated immediately following use.

Road Decommissioning

The project plans to decommission up to 9.86 miles of road using techniques ranging from administratively removing the road from the system to fully restoring the slope to near natural contours. The level of treatment is determined site-specifically based on the road's current condition and location, and whit is needed to meet the objective to hydrologically stabilize the road (Two Eagle Engineering Effects Report). Decommissioning of these system roads would return these features to the productive land base to be managed according to NFMA requirements for soil productivity and forest cover. These segments are currently closed to all but administrative use, and many have well-established vegetation at this time. The lack of any significant efforts to address soil productivity impairment on these areas would result in persistence of physical soil impacts in excess of 30 to 70 years. Measurable increases in soil productivity on these areas are not expected during the temporal extent of this analysis.

Summary

Since the 1990 Forest Plan, the level of concern for maintaining soil productivity has greatly increased. This increase has been accompanied with implementation of management practices that protect the soil. These changes include the use of excavators instead of dozers for mechanical site preparation, use of designated skid trails, operating when soils are dry or when winter conditions would protect soil productivity, log forwarder systems, and use of slash layers to reduce effects on skid trails. In addition, vegetation management projects are audited for compliance with BMPs and are monitored as specified in the NEPA decision, both of which contribute to better results.

Table 8 below shows the expected new and total detrimental soil conditions for each alternative in the Two Eagle project area. The final DSCs were calculated by adding existing DSCs with the new DSCs expected to result from the project activities in each alternative. Units are shaded in the table below because they are expected to exceed the minimum of 80 percent acceptable productivity potential because of existing detrimental soil conditions and each alternative activities.

Proposed Action units expected to exceed 20% are 4, 5, 17, 25, 26, 27, 29, 31, 34, 48, 53, 55, 56, 58, 60, 62, 63, 88, 90, 92, 93, 94, 96, 115, 116, 117, 126, 127, 130, 139, 140, 148, 151, 152, 153, 158, 159, 162, 163, and 164. Alternative 2 Modified units expected to exceed 20% are 4, 5, 17, 25, 26, 27, 29, 31, 34, 48, 53, 55, 56, 58, 60, 62, 63, 88, 90, 92, 93, 94, 96, 115, 116, 117, 126, 127, 129, 130, 133, 139, 140, 145, 148, 151, 152, 153, 158, 159, 161, 162, 163, and 164. Alternative 3 units 4, 5, 26, 27, 53, 56, 60, 63, 88, 90, 92, 93, 94, 96, 115, 116, 117, 126, 127, 130, 139, 140, 148, 151, 152, 153, 158, 159, 162, 163, and 164.

Restoration activities would occur after ground-based activities are complete. The contractor would be required to subsoil or decompact landings and used or old skid trails as needed to bring DSCs below 20% in units that exceed DSC minimums (Soils PDC 15). Additional protection of the soil resource would be afforded by having ground-based operations only when soils are dry, snow covered, or frozen. Grapple piling and burning generated minimal detrimental disturbance. Mastication and hand treatment would not be expected to result in any additional detrimental impacts. Literature and local monitoring on soils similar to those in the project area indicate that skyline logging would meet the Regional Soil Quality Standards. The effects from skyline harvest would impact less soil than ground-based harvest when used on the appropriate slopes.

Several studies discuss the effectiveness of subsoiling as a soil restoration activity. Seedling survival and growth can be improved by 39 percent after tilling of compacted soils (Froehlick and McNabb, 1983). Subsoiling restores biological processes that are reduced by soil compaction (Dick et al., 1988). In general, tilling or scarifying a compacted soil improves productivity by reducing the resistance of soil to root penetration and providing improved soil drainage and aeration to enhance seedling establishment and tree growth (Bulmer, 1998). These conditions also improve the environment for soil microorganisms. Soil restoration is not the immediate result of ripping, planting, or any other activity. The goal of soil restoration is to create favorable conditions for impaired soils to begin the recovery process.

Table 8. New DSCs for Alternative 2, 2 Modified and 3 in the Two Eagle Project

Unit	Acres	Existing Condition DSC	Potential DSC Percent Increase						Final DSC Percent		
			Vegetation Treatments			Temporary Roads					
			Proposed Action	Alt 2 Modified	Alt 3	Proposed Action	Alt 2 Modified	Alt 3	Proposed Action	Alt 2 Modified	Alt 3
1	31	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
2	38	5%	12%	12%	12%	1%	1%	1%	18%	18%	18%
3	31	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
4	15	8%	12%	12%	12%	0%	0%	0%	20%	20%	20%
5	40	18%	12%	12%	12%	0%	0%	0%	30%	30%	30%
7	10	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
8	26	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
9	12	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
11	21	5%	2%	2%	2%	0%	0%	0%	7%	7%	7%
12	12	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
13	18	6%	2%	2%	2%	2%	2%	2%	9%	9%	9%
14	10	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
15	12	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
16	16	5%	12%	12%	12%	1%	1%	1%	17%	17%	17%
17	5	5%	12%	12%	12%	4%	4%	2%	20%	20%	18%
18	17	5%	2%	2%	2%	0%	0%	0%	7%	7%	7%
21	66	16%	2%	2%	2%	1%	1%	1%	19%	19%	19%
22	99	5%	2%	2%	0%	1%	1%	0%	7%	7%	5%
23	29	6%	12%	12%	12%	1%	1%	1%	18%	18%	18%
24	16	6%	12%	12%	12%	0%	0%	0%	17%	17%	17%
25	8	9%	13%	13%	11%	0%	0%	0%	21%	21%	19%
26	10	23%	13%	13%	11%	0%	0%	0%	36%	36%	34%

27	33	23%	13%	13%	11%	0%	0%	0%	36%	36%	34%
28	20	6%	12%	12%	12%	0%	0%	0%	17%	17%	17%
29	13	6%	13%	13%	11%	3%	3%	3%	21%	21%	19%
30	8	5%	2%	2%	2%	3%	3%	3%	10%	10%	10%
31	9	5%	13%	13%	0%	2%	2%	0%	20%	20%	5%
32	8	5%	12%	12%	12%	1%	1%	1%	17%	17%	17%
33	18	5%	12%	12%	12%	3%	3%	2%	19%	19%	18%
34	49	7%	13%	13%	0%	0%	0%	0%	20%	20%	7%
35	2	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
36	9	5%	13%	13%	0%	0%	0%	0%	17%	17%	5%
37	5	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
38	21	5%	13%	13%	0%	2%	2%	0%	19%	19%	5%
40	23	5%	12%	12%	0%	1%	1%	0%	17%	17%	5%
41	7	5%	12%	12%	12%	1%	1%	1%	18%	18%	18%
42	10	5%	12%	12%	0%	0%	0%	0%	16%	16%	5%
43	92	5%	13%	13%	11%	0%	0%	0%	17%	17%	15%
45	50	5%	12%	12%	12%	1%	1%	1%	18%	18%	18%
48	15	5%	13%	13%	11%	3%	3%	3%	20%	20%	18%
49	8	5%	13%	13%	11%	0%	0%	0%	17%	17%	15%
50	13	5%	12%	12%	0%	0%	0%	0%	16%	16%	5%
51	18	5%	12%	12%	0%	0%	0%	0%	16%	16%	5%
52	27	5%	13%	13%	0%	0%	0%	0%	17%	17%	5%
53	38	23%	0%	13%	0%	0%	0%	0%	23%	36%	23%
54	11	5%	12%	12%	0%	3%	3%	0%	19%	19%	5%
55	14	17%	12%	12%	0%	0%	0%	0%	29%	29%	17%
56	5	23%	12%	12%	9%	0%	0%	0%	35%	35%	32%
57	7	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
58	6	5%	12%	12%	0%	4%	4%	0%	20%	20%	5%
59	10	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
60	14	23%	12%	12%	12%	0%	0%	0%	35%	35%	35%
62	10	14%	13%	13%	0%	0%	0%	0%	27%	27%	14%
63	16	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
64	7	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
66	54	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
68	18	6%	12%	12%	12%	0%	0%	0%	17%	17%	17%
69	9	5%	0%	13%	0%	0%	0%	0%	5%	17%	5%
71	22	5%	12%	12%	0%	0%	0%	0%	16%	16%	5%
74	22	5%	2%	2%	2%	1%	1%	1%	7%	7%	7%
75	13	6%	12%	12%	12%	0%	0%	0%	17%	17%	17%
78	24	5%	12%	12%	12%	0%	0%	0%	17%	17%	17%
79	11	6%	12%	12%	12%	0%	0%	0%	17%	17%	17%
80	31	5%	12%	12%	12%	1%	1%	1%	17%	17%	17%
84	1	5%	9%	9%	9%	2%	0%	2%	15%	13%	15%
85	25	5%	12%	12%	12%	0%	0%	0%	17%	17%	17%
86	14	5%	12%	12%	12%	0%	0%	0%	16%	16%	16%
88	23	19%	12%	12%	12%	0%	0%	0%	30%	30%	30%
89	65	6%	13%	13%	11%	0%	0%	0%	19%	19%	17%
90	25	22%	0%	0%	0%	0%	0%	0%	22%	22%	22%
92	32	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
93	7	22%	0%	0%	0%	0%	0%	0%	22%	22%	22%
94	19	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
95	2	6%	9%	9%	0%	0%	0%	0%	15%	15%	6%

96	7	16%	12%	12%	12%	0%	0%	0%	28%	28%	28%
97	17	5%	13%	13%	11%	2%	2%	1%	19%	19%	16%
98	13	5%	13%	13%	11%	1%	1%	0%	18%	18%	15%
102	10	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
112	4	9%	9%	9%	0%	0%	0%	0%	17%	17%	9%
113	1	10%	9%	9%	0%	0%	0%	0%	19%	19%	10%
115	34	23%	12%	12%	12%	0%	0%	0%	34%	34%	34%
116	52	21%	12%	12%	12%	0%	0%	0%	33%	33%	33%
117	27	22%	13%	13%	11%	1%	1%	1%	35%	35%	33%
118	22	5%	2%	2%	2%	0%	0%	0%	7%	7%	7%
119	8	5%	2%	2%	2%	0%	0%	0%	7%	7%	7%
120	14	5%	9%	9%	9%	0%	0%	0%	13%	13%	13%
121	13	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
123	18	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
124	27	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
126	11	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
127	6	23%	0%	13%	0%	0%	0%	0%	23%	36%	23%
128	13	5%	0%	13%	0%	0%	0%	0%	5%	18%	5%
129	7	7%	0%	13%	0%	0%	0%	0%	7%	20%	7%
130	40	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
131	8	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
132	18	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
133	3	8%	0%	13%	0%	0%	0%	0%	8%	21%	8%
135	18	5%	0%	13%	0%	0%	0%	0%	5%	17%	5%
138	31	6%	0%	13%	0%	0%	0%	0%	6%	19%	6%
139	11	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
140	21	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
145	69	13%	0%	13%	0%	0%	0%	0%	13%	26%	13%
147	31	5%	0%	13%	0%	0%	0%	0%	5%	17%	5%
148	107	20%	0%	0%	0%	0%	0%	0%	20%	20%	20%
149	6	5%	0%	12%	0%	0%	0%	0%	5%	16%	5%
150	23	17%	0%	0%	0%	1%	1%	1%	18%	18%	18%
151	23	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
152	55	23%	0%	13%	0%	0%	0%	0%	23%	36%	23%
153	27	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
156	30	5%	0%	0%	0%	0%	0%	0%	5%	5%	5%
157	21	5%	0%	13%	0%	0%	0%	0%	5%	17%	5%
158	10	22%	0%	0%	0%	0%	0%	0%	22%	22%	22%
159	15	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
160	35	5%	0%	13%	0%	0%	0%	0%	5%	18%	5%
161	22	11%	0%	13%	0%	0%	0%	0%	11%	23%	11%
162	7	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
163	8	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
164	19	23%	0%	0%	0%	0%	0%	0%	23%	23%	23%
165	29	14%	0%	0%	0%	0%	0%	0%	14%	14%	14%
166	5	7%	0%	0%	0%	0%	0%	0%	7%	7%	7%
Total Acres	**2548**								**438**	**483**	**338**

Organic Matter

All proposed treatments would leave varying amounts of organic matter on the site. Reductions in organic matter content reverse quickly as vegetation is established. Organic debris accumulates on the surface and roots grow and are decomposed in the soil. These organic materials break down and release nutrients and improve the quality of the soil by improving its structure and reducing compaction and other DSCs. Coarse woody debris (greater than three inches in diameter) would be retain at approximately 5 to 10 tons per acres on dry ponderosa pine sites and 10 to 15 tons per acre on mixed conifer sites (Adapted from DeBano, Neary, and Ffolliott, 1998). The total amount of nutrients on a site would likely be reduced where organic matter would be removed or displaced. However, plant available nutrients mineralized from organic matter would increase due to increased incoming solar radiation and soil moisture. These conditions would accelerate the decomposition of the remaining organic matter and the release of plant-available nutrients in the treated stands (Harvey et al., 1994). After project implementation, competition between trees would be reduced because fewer trees would remain on the sites. This situation could result in more available nutrients and water for the remaining trees, potentially conferring greater growth, vigor and disease resistance (Power et al., 2005). Nutrients in soil and organic matter are not the only nutrients available to the forest vegetation. In logging followed by low-severity broadcast burning, there would be no long-term depletion of nitrogen reserves because lost nitrogen would be more than replenished by inputs from precipitation and by biological nitrogen fixation over a rotation of 100 to 150 years (Jurgensen et al., 1981).

Regeneration Harvest

These treatments would remove the most live vegetation and have the potential to remove more amounts of organic matter than intermediate harvests. Units proposed for grapple pile burning or broadcast burning would leave nutrients associated with the slash on the site to be used by the remaining forest vegetation. All harvest prescriptions would leave a portion of the existing stand on the site. Remaining living trees in stands would serve as potential nutrient sources on the site.

Commercial Thinning and Mechanical Non-Commercial Thinning

These treatments would leave a large portion of the existing stand on site. Units proposed for grapple pile burning or broadcast burning would leave nutrients associated with slash on the site to be used by the remaining forest vegetation. Grapple piling would reduce organic material on sites while reducing hazardous fuel loads. A variety of organic material would remain on the site after project implementation. Burn effects of grapple-piled slash are based on definitions in Region 6 Soil Quality Standards. Pile burn effects qualify as DSC if they meet criteria for severe burn severity and occupy an area of at least 100 square feet. Local data from past projects in a similar area (Wallowa-Whitman, 2004) indicates grapple piles would occupy 1 to 2 percent of units (4 to 7 piles/acre up to 12 feet in diameter) and are typically more than 100 square feet. The range of effects from burning these piles would be an additional 1 to 2 percent DSC within an activity unit. Mastication treatments increase woody debris and result in a net increase of forest floor carbon. These types of increases do not appear to decrease nitrogen and phosphorus availability (Ryan et al., 2009). Landing slash burning is typically associated with skyline landings since the whole tree is brought to and harvested at the landing. Local data (Wallowa-Whitman NF, 2004) indicates slash piles at skyline landings are typically 100-1000 square feet in size. When burned, these piles would create high-burn severity and cause about 0.5 to 1 percent DSC (ibid.).

Hand Non-Commercial Thinning

Limiting hand pile size to less than 50 square feet could reduce surface organic horizon loss and limit soil heating. Pile burning when duff moisture is moist or wet may also reduce organic matter loss and soil heating (Soils PDC 9). The amount of nutrients lost as particulate matter would be minor. Ash from burned hand piles would contain nutrients available to emergent vegetation, but no significant increases in nitrogen and phosphorus are anticipated (Seymour et al., 2005). Hand thinning treatment units would have slash dispersed throughout the unit. Organic matter would not be removed, and there would be no measurable effects to the forest floor.

Landscape Burning

The effect of fire on soil is described as burn severity, which depends on the duration of burning and intensity (Certini, 2005). Long-duration burns tend to reach higher temperatures and penetrate deeper into soil, resulting in more soil microbial kill and consumption of soil organic matter (ibid.). These burns result from burning of heavy ground fuel, such as with downed logs and large slash piles. Short-duration burning can be associated with fast-moving wildfire that blackens all the trees but leaves some of the forest floor intact. This usual results in low- to moderate-burn severities on the ground, with heat only penetrating a few centimeters (Hartford et al., 1992). Prescribed fire activities that result in dominantly low-to moderate-burn severities would best preserve soil productivity. The amount of nutrients available to plants would increase as a result of the burning. Areas burned under conditions that produce light or moderate burn severity would vegetate quickly due to viable seeds or roots that could produce more plants and the complement of microorganisms and nutrients remaining on site (Ryan and Noste, 1985). Proposed burn conditions would allow many plants to quickly return to the burned sites from unburned roots and seeds in the soil. Post-fire vegetation response would utilize available nutrients, reducing nutrient leaching. Native forest vegetation would remain on the site, including some of the existing trees. Jackpot burning may or may not be any different than broadcast burning depending on fuel loadings and distribution. Through jackpot burning, the heavier concentrations are burned as the primary focus and if burned under wetter conditions can be less impacting than broadcast burning.

The ultimate goal of this effort is to maximize the intended vegetative response while minimizing resource effects. Fire intensity represents the magnitude of produced heat. It is distinct from burn severity. Fire management personnel would design burn plans and implement burn activities to minimize the occurrence of high-burn severity, while achieving burn intensities adequate to attain objectives.

Summary

All proposed units would leave live vegetation. Most of the living grass, forb, and shrub components would be retained in all of the proposed units. Many live trees would remain on all the sties with the fewest trees left on the proposed regeneration harvest units. The material that remains in all of the units would provide an active, microorganism-rich organic layer on the soil surface.

Soil Biological Activity

Post-fire recovery of soil microorganisms occurs rapidly, frequently resulting in population levels greater than before the fire (Jurgensen et al., 1977). Less disturbed areas of soil play an important role in inoculating soil lacking or having reduced populations of soil microorganisms (Borchers et al., 1990). Unburned areas within burns, adjacent undisturbed areas, large woody debris and soil that have only minor amounts of disturbance contain propagules for fungi, bacteria and other soil organisms and that these propagules can be freely dispersed by wind, animals and other agents (Borchers et al., 1990).

The variety of organic matter left on the proposed harvest areas would benefit soil microorganisms by providing substrate and habitat. Microbial measures in harvest areas are expected to meet, or exceed, levels in unharvested stands within 40 years (Page-Dumroese et al., 2015). All alternatives would leave both dead and live trees. All alternatives and all proposed activity areas would have less than 20 percent of the area detrimentally disturbed. Many areas would be undisturbed by equipment. These areas would be a source of propagule in disturbed sites. The amounts of live and dead trees to be left in the proposed harvest areas are described in Chapter 2.

Soil compaction, puddling, rutting, and displacement reduce gas exchange and could potentially affect soil microorganism survival. Favorable habitat for soil organisms would be maintained because all proposed activity areas would be designed to reduce soil disturbance to meet Regional soil standards.

Summary

Because the amount of detrimental physical soil changes would be minimized and because organic matter in various forms would remain on the proposed units, the effects to soil microorganisms would be minor. Soil microorganisms are mobile. They can quickly re-colonize disturbed sites from adjacent, undisturbed sites. A variety of organic matter would remain on all sites, including living trees and other forest vegetation. In addition, the organic layer on the soil surface would be retained over at least 80 percent of the area, providing habitat and nutrients for soil microorganisms.

Direct and Indirect Effects: Soil Erosion

Displacement and erosion, the loss of topsoil, is a long-term and perhaps a permanent loss of soil productivity. However, management practices outlined in the Design Criteria would reduce the occurrence of displacement and erosion to within the Region 6 Soil Quality Standards. Where there is a risk of soil erosion, it would be minimized by implementing the following management practices:

- Reducing the area where equipment operates,
- Locating landings on relatively flat ground that can be properly drained,
- Locating skid trails on slopes less than 35 percent that have soils with a low or moderate erosion hazard,
- Using erosion control features, such as water bars, replanting, and placing slash on disturbed soils.

Sediment from the permanent transportation system has direct effects on water quality, but is not a component of the soil quality assessment process. These effects are evaluated in the Watershed and Fisheries Effects Section of this EA.

Commercial Thinning and Mechanical Non-Commercial Thinning

Management activities that leave organic matter on the soil surface reduce soil erosion potential. Organic matter and vegetation retained after ground based operations would reduce surface erosion potential. A majority of these landtypes are characterized by 10 to 50 percent slopes and soils with increased infiltration rates because of volcanic ash presence The high rock fragment content of most subsurface horizons also promotes water movement through the soils. Soil erosion from these activities are likely to be within background rates and will decreases over time as vegetation increases. Any increase in overland flow from existing areas of compacted soil would likely be buffered by existing forest floor and/or new accumulations of woody debris.

Within treatment units, the dominant erosion potential, when the forest floor has been disturbed, is low to moderate. Treatment units with high erosion potential when the forest floor has been disturbed are units 3, 5, 7, 8, 12, 13, 14, 18, 22, 31, 34, 35, 36, 38, 52, 57, 69, 71, 74, 90, 92, 93, 94, 97, 102, 121, 124, 126, 127, 130, 131, 132, 139, 140, 147, 148, 150, 151, 152, 156, 160, 162, and 163.These units would be required to have a minimum of 45 to 60 percent effective ground cover following cessation of any soil-disturbing activities (per Region 6 Soil Quality Standard) (Soils PDC 12). Units 30, 42, 43, 49, 52, 53, 55, 56, 62, 63, 71, 88, 90, 115, 116, 118, 119, 130, 145, 153, 162, and 163 have flashy runoff potential and require careful erosion control planning and implementation. This includes ensuring that before spring runoff necessary water control structures are installed and maintained on skid trails over 10% slope after all ground-disturbing activities, ensuring erosion control structures are stabilized and working effectively, and ensuring that effective ground cover is left within the unit after all ground-disturbing activities (Soil PDC 10, 12). Mastication treatments are not anticipated to result in any increase of soil erosion in the proposed units. Existing areas of bare soil may benefit from additions of masticated material as effective ground cover.

Table 9. High surface erosion hazard when disturbed in each action alternative

	Alt 2	Alt 2 Mod	Alt 3
Acres of Treatment with High Surface Erosion (Disturbed)	1130	1130	967

Hand Non-Commercial Thinning

Maintenance of infiltration rates and effective ground cover of soils is necessary to prevent erosion. The lack of compactive forces and small pile burning associated with hand thinning and piling would not result in a significant reduction in infiltration rates over undisturbed soil. Although reductions in effective ground cover would be expected at burn pile locations, the lack of accompanying increase in overland flow and rapid establishment of live plant cover would reduce short-term soil erosion. No long-term soil erosion is anticipated from this treatment. Soil erosion would be unlikely to occur as a result of the pre-commercial thinning treatments. Masticated material and hand thinning slash would add cover to the soil surface, reducing the risk of erosion. Hand piling would not increase risk of soil erosion.

Landscape Burning

A majority of the broadcast burning would occur on soils with a low soil erodibility hazard. Post-fire vegetative response would be rapid, regardless of burn severity and areas that burn intensely would have sufficient organic material and vegetative response to reduce risks to soil erosion (Lentile et al., 2007). Soil erosion rates would decrease as vegetation and effective ground cover are re-established.

Culvert Replacement

Culvert installations and replacement would cause some short-term soil erosion during the construction phase, but would result in improved road drainage and a reduction of road failure risk during high flow events. Culverts would be installed during the instream work window, and would be installed on Category 4 streams during dry channel conditions limiting potential for transport of soils as sediment.

Direct and Indirect Effects: Soil Stability

A majority of the project area showed high slope stability during field investigations of proposed activity areas. Areas that had dry ravel and unstable slopes were associated with roads. These areas will be mitigated with project design criteria which includes drainage work (springs, culvert replacements) to improve road drainage and reduce road failure risk during high flow events, as well as stabilization of landslide areas that affect system roads (Soils PDC 14). Temporary Roads with high mass failure hazard include segments of T-3, T-5, and T-9 in all alternatives. Units with high mass failure hazard include 5, 13, 52, 71, 74, 90, 116, 130, 132, 162, and 163. Units with moderate to high mass failure hazard include 30, 42, 43, 49, 53, 55, 56, 62, 63, 88, 115, 118, 119, 145, and 153.

Table 11. Mass failure hazard and temporary roads in each action alternative

	Alt 2	Alt 2 Mod	Alt 3
Miles of Temporary Roads with Unstable Soils	0.34	0.34	0.34

Cumulative Effects

Present and Reasonably Foreseeable Activities Relevant to Cumulative Effects Analysis

Estimated levels of soil disturbance associated with proposed activities in conjunction with past and existing levels of soil disturbance would result in short term incremental increases in soil DSC followed by longer term recovery and reductions in DSC as revegetation, freeze thaw and other natural processes occur. Ongoing noxious weed treatments would not create any measurable soil impacts. Eagle Creek Salvage Sale logging activities will not overlap spatially with this project. There is active grazing in the Goose Creek and Big Creek Allotments but most of the grazing soil impacts are within riparian areas outside of the proposed activity area. Livestock water developments have limited areas of compaction or trampling of soil, and the potential soil displacement would be too limited in aerial extent to be counted in DSC calculations (USDA Forest Service, 1998). Other ongoing activities that may impact soils include recreation activities near Eagle Creek Wild and Scenic River, Two Color Guard Station, Two Color Campground, Boulder Park Recreation Residences, Boulder Park Campground, West Eagle Trail 1934, Main Eagle Trail 1922, Two Color Lake Trail 1932, dispersed camping, firewood cutting, OHV use, and snowmobile routes. These should not measurably increase in the foreseeable future. These activities in combination with anticipated effects on soils associated with implementation of any of the action alternatives are not expected to add to adverse cumulative watershed effects for soils because of their limited aerial extent and application of mitigation and design features aimed at minimizing soil impacts.

Table 12: Summary of resource indicators and measures for each alternative

Resource Indicator		Measure	Alternative 1	Alternative 2	Alternative 2 Modified	Alternative 3
Soil Productivity	>80% acceptable productivity potential	Acres of detrimental soil conditions	158	438	483	338
Soil Erosions	Soil erosion hazard	Acres of proposed ground-based activities on landtypes with high surface erosion hazard	0	1130	1130	967
Soil Stability	Soil mass failure hazard	Miles of temporary roads on landtypes with high mass failure hazard	0	0.34	0.34	0.34

3. Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.

There are wetlands present in the project area. Wetlands are considered to be a sensitive soil type, however seeps, springs, and wetlands would have riparian buffers that restrict equipment entry. Therefore, the effects of the proposed action to these sensitive soil types do not rise to the level of significance for intensity factor three.

10. Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

Relevant laws and requirements include the Umatilla Forest Plan, Organic Administration Act of 1897, Bankhead-Jones Act of 1937, The Multiple Use-Sustained Yield Act of 1960, 36 CFR 219.20, The National Forest Management Act of 1976, FSM 2500 Watershed and Air Management, and Region 6 Soil Quality Standards. Project design criteria and BMPs would prevent significant effects to the soil resource. For this reason, the proposed action is consistent with the above laws and requirements, and it does not rise to the level of significance for intensity factor ten.

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APPENDIX A – TITLE 2520 – WATERSHED PROTECTION AND MANAGEMENT

2520.2 - Objective. To meet direction in the National Forest Management Act of 1976 and other legal mandates. To manage National Forest System lands under ecosystem management principles without permanent impairment of land productivity and to maintain or improve soil and water quality.

1. Plan and conduct land management activities so soil and water quality are maintained or improved.

    a. Soil quality is maintained when soil compaction, displacement puddling, burning, erosion, loss of organic matter and altered soil moisture regimes are maintained within defined standards and guidelines.

    b. Water quality is maintained when sedimentation and nutrient enrichment from surface erosion and mass wasting processes is within ranges of natural variability.

2. The Pacific Northwest Region shall have implementable, measurable soil quality standards and guidelines that can be monitored and are supportive of land management objectives.

2520.3 - Policy. Design and implement management practices which maintain or improve soil and water quality. Emphasize protection over restoration.

When initiating new activities:

1. Design new activities that do not exceed detrimental soil conditions on more than 20 percent of an activity area. (This includes the permanent transportation system.)

2. In areas where less than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent.

3. In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.

2521 - WATERSHED CONDITION ASSESSMENT

2521.03 - Policy. Assess current Forest-wide soil quality conditions and trends. Conduct monitoring activities to determine if soil quality objectives, standards and guidelines are met and are in accord with current scientific knowledge.

1. Soil Quality Standards: The following regional standards are thresholds beyond which soil quality is adversely impacted.

Leave a minimum of 80% of an activity area in an acceptable soil quality condition. Detrimental conditions, as defined below, also include landings and system roads. Detrimental soil quality conditions and the accompanying criteria for determining when and where these conditions occur include:

a. Compaction, Displacement, Puddling, Severely Burned.

(1) Detrimental Compaction.

(a) Volcanic Ash/Pumice Soils (Soils with Andic Properties). An increase in soil bulk density of 20 percent, or more, over the undisturbed level.

(b) Other Soils. An increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macropore space reduction of 50 percent or more, and/or a reduction below 15 percent macro porosity.

Assess changes in compaction by sampling bulk density, macro porosity, or penetration resistance in the zone in which change is relatively long term and that is the principal root development zone. This zone is commonly between 4 to 12 inches in depth.

(2) Detrimental Puddling. Detrimental puddling is when the depth of ruts or imprints is six inches or more. Soil deformation and loss of structure are observable and usually bulk density is increased.

(3) Detrimental Displacement. Detrimental displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.

(4) Detrimental Burned Soil. Soils are considered to be detrimentally burned when the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next one-half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five feet in width.

b. Erosion

(1) Detrimental Surface Erosion. For effectiveness monitoring, detrimental erosion is visual evidence of surface loss in areas greater than 100 square feet, rills or gullies and/or water quality degradation from sediment or nutrient enrichment. (See FSM 2532)

For planning or implementation monitoring to meet acceptable levels of soil loss and soil management objectives, the minimum percent effective ground cover following cessation of any soil-disturbing activity should be:

Minimum Percent Effective Ground Cover

Erosion Hazard Class	1st Year	2nd Year
Low (Very slight-slight)	20-30	30-40
Medium (Moderate)	30-45	40-60
High (Severe)	45-60	60-75
Very High (Very Severe)	60-90	75-90

The above erosion hazard classes are from Soil Resource Inventories, ecological unit inventories, the Region 5 Erosion Hazard Rating System (R5-2500-14) and locally adapted standard erosion models and measurements.

(2) Detrimental Soil Mass Wasting. Detrimental mass wasting is visual evidence of landslides associated with land management activities and/or degrades water quality. (See FSM 2532)

Plan activities to avoid acceleration of natural landslide rates. Make Level I, II, or III stability analyses as appropriate. (Ref. USDA FS EM-7170-13 Vol. 1-3)

2. Soil Quality Guidelines:

a. Organic Matter. Organic matter is critical for long-term site productivity and ecosystem sustainability. It should be maintained in amounts sufficient to prevent short or long-term nutrient and carbon cycle deficits and to avoid detrimental physical and biological soil conditions.

(1) Fine Organic Matter - Fine organic matter includes plant litter, duff, and woody material less than 3 inches in diameter. Determine minimum organic layer thickness and distribution locally according to groups of similar soils or ecological types (FSH 2090.11).

(2) Coarse Woody Material - Coarse woody material is greater than 3 inches in diameter. Management of coarse woody material has different degrees or standards depending on specific multi-resource objectives. The direct benefits to soils vary widely, depending on ecological type.

Adjust the minimum logs, or branches, per acre according to potential for ecological type, or groups of similar types.

b. Soil Moisture Regime. Plan land management activities so that the soil moisture regime remains unchanged (except for activities that restore natural water tables). Detrimental conditions are changes in soil drainage classes (Soil Survey Manual and Handbook) or aquic conditions (Soil Taxonomy Handbook) that are incompatible with management objectives.

Evaluate the effect of management induced water table or subsurface flow changes on plant growth or potential community composition.

3. Application of Soil Quality Standards

The standards and guidelines apply to lands where vegetation and water resource management are the principal objectives. (For example, timber sales, grazing pastures or allotments, wildlife habitat, riparian reaches, and burn areas.) These standards and guidelines do not apply to intensively developed sites such as mines, developed recreation sites, administrative sites, or rock quarries.

a. Planning. Use soil quality standards to guide the selection and design of management practices and prescriptions on a watershed scale. Evaluate existing soil conditions on all ownerships within the watershed and consider cumulative effects with the addition of proposed actions on ecosystem sustainability and hydrologic function. On a planned activity area, evaluate existing soil conditions and design activities to meet soil quality standards. Document adjustments to management practices, soil conservation practices or restoration techniques necessary to meet threshold values for the affected soil properties and watershed conditions.

b. Monitoring.

(1) Watershed Condition Classes. Each forest needs to monitor watershed condition (FSM 2521.1) and track trends in overall soil quality over time through landscape scale assessments such as watershed analysis (MAR 82.5, 82.6, 82.7.)

(2) Implementation Monitoring. During and following completion of projects, document whether management practices are, or were, implemented as prescribed.

(3) Effectiveness Monitoring. Document if the cumulative effects from applied management practices within an activity area met soil quality standards as defined. Base assessments on appropriate sampling design and procedures. For example: R6-RWM-146-1983, "Sampling Some Physical Conditions of Surface Soils." Appropriate quantitative or qualitative techniques may be used.

(4) Validation Monitoring. Where there are significant gaps in knowledge, collaborate with research organizations, adjoining Forests, Universities, Private Industry and other local interested groups to establish studies to fill the knowledge gaps.

2521.04 - Responsibilities

2521.04c - Forest Supervisors.

1. Forest Supervisors are responsible for:

   a. Ensuring Forest Plans include soil quality standards and guidelines and setting local surface organic matter standards and guidelines.

   b. Assessing current Forest-wide soil quality conditions relative to watershed condition classes I, II and III. (Ref. MAR 82.5, 82.6, 82.7 and FSM 2521.1)

   c. Providing training for application of soil management prescriptions, standards and objectives to forest personnel.

   d. Evaluating the effectiveness of soil quality standards and procedures, measuring them through monitoring and periodic reviews, and recommending adjustments to the Regional Forester.

   e. Reporting monitoring results to the Regional Forester.

2. District Rangers are responsible for:

   a. Ensuring that land management activities are consistent with soil quality standards and guidelines.

   b. Implementing measures necessary to meet soil quality standards in environmental documents.

   c. Conducting post activity evaluations to determine if soil quality standards have been met.

2521.05 - Definitions.

Activity Area. The total area of ground impacting activity, and is a feasible unit for sampling and evaluating. Some examples are: a sale contract unit, pasture, allotment, meadow, riparian reach, burned area.

Bulk Density. The mass of dry soil per unit volume. Determine volume before drying to a constant weight at 105 degrees C. Correct this figure for weight and volume of coarse fragments greater than 2 mm in diameter.

Ecological Type. A category of land having a unique combination of potential natural plant community, soil, landscape features, climate, and differing from other ecological types in its ability to produce vegetation and respond to management. (Ref. FSH 2090.11)

Project Area. The area in which project analysis occurs for proposed specific activities.

Restoration. Treatments that restore vital soil functions to inherent range of variability. It is recognized that treatments may need to occur over a period of years and may need to be maintained.

Soil Compaction. Compaction of soil increases soil bulk density and soil strength and decreases porosity as a result of the application of forces such as weight and vibration.

Soil Displacement. Soil displacement is the lateral movement of soil from one place to another by mechanical forces such as equipment blades, vehicle traffic, or logs being yarded.

Soil Mass Wasting. Soil mass wasting is the detachment and movement of soil or surface mantle material by gravity. Some landslides fail in a single mass or single event and move downslope to cause debris slides and avalanches. Other landslides detach and move slowly over a period of years.

Soil Puddling. Soil puddling is a physical change in soil properties, under moist conditions, due to shearing forces that destroy soil structure and reduce porosity. It occurs in slightly plastic, plastic, and very plastic soils.

Soil Quality. The capacity of a specific soil to function within natural or altered land use boundaries to sustain or improve plant or animal productivity, water quality and flows, air quality, and human health and habitation.

Surface Erosion. Surface erosion is the detachment and transport of individual soil particles by wind, water, or gravity. Surface erosion can occur as the loss of soil in a fairly uniform layer (sheet erosion, dry ravel) or rills or gullies.

Water Quality. (For these purposes) Changes in water conditions from erosion, sedimentation and nutrient enrichment